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ABSTRACT

The Zimbabwe Secondary School Science Project (ZIM-SCI) developed student study guides, corresponding teaching guides, and science kits for a low-cost science course which could be taught during the first 2 years of secondary school without the aid of qualified teachers and conventional laboratories. This ZIM-SCI study guide presents activities and experiments for a two-part unit dealing with various aspects of electricity. Major areas investigated include: simple circuits; conductors and insulators; electrical symbols; series and parallel circuits; measurement of current in series and parallel circuits; measurement of electrical energy; short circuits; fuses; resistance; and voltage, current, and resistance. Information is provided throughout the unit to help students understand the concepts behind the activities and experiments. (JN)

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ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

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YEAR 2

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STUDY GUIDE UNIT I 1

UNDERSTANDING ELECTRICITY

SE 043 856

UNIVERSITY OF ZIMBABWE
AND MINISTRY OF EDUCATION AND CULTURE

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MAY 1983

ZIM-SCI

ZIMBABWE SECONDARY SCHOOL SCIENCE PROJECT

GENERAL SCIENCE

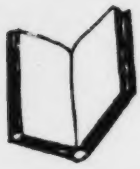
STUDENTS: Please read this carefully. It will help you.

How you will study

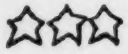
This Study Guide comes to you with a kit of apparatus. Both things are part of a study programme leading you to an understanding of aspects of science. In this course you will be carrying out experiments. The Study Guide will help you to understand the scientific principles behind the experiments.

Your work should be done as you are instructed, either by the teacher or the Study Guide.

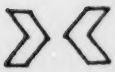
To help you to see quickly what you must do, the Study Guide uses these symbols:



for "Read and revise your notes and Study Guide"

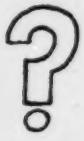


for "Take note of an important point that you should learn"



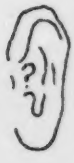
for "Summary. This is to help you to go over what you have learned"

for "Experiment"
When you see this sign, read the instructions carefully from beginning to end before you start to do the experiment.



for "How much do you know?"
This is for you, to help you to test whether you are remembering what is important.

for "Written work"
This is when you must answer questions in writing.



for "Listen to the teacher and do exactly what the teacher tells you to do"

for "Activity"
This symbol will appear whenever you are asked to do something without your apparatus.

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AIMS OF THIS UNIT

At the end of this Unit you will be able to:-

1. Demonstrate that electricity is a form of energy which can be converted to other forms of energy e.g. heat and light.
2. Draw a simple D.C. circuit including a switch.
3. State the difference between conductors and insulators.
4. Recognise common electrical circuit symbols.
5. State the difference between a cell and a battery.
6. Demonstrate the differences between series and a parallel circuits.
7. Describe electrical current.
8. Describe the concept of voltage and its connection with current and energy.
9. Demonstrate the measurement of current and voltage using an ammeter and voltmeter respectively.
10. Trace energy changes in a circuit.
11. Explain the difference between a good and a poor source of electrical energy.
12. Demonstrate what a short circuit is, and state what dangers can be caused by it.
13. Describe what a fuse is and its use in a circuit.
14. Explain resistance by analogy with friction.
15. Describe the general relationship between current, voltage and resistance.

UNIT 1

STUDENT'S GUIDE

In Unit B you learnt about Energy. There are different forms of energy. Energy cannot be created or destroyed but can be converted from one form to another. Let us look at a few examples of energy conversion:

Light energy ---> Electrical energy
(solar cell)

Chemical energy ----> Electrical energy ---> light energy
(torch cell) (torch bulb)

Kinetic Energy (moving dynamo) ---> electrical energy ---> light energy (light bulb)

These are but a few examples of energy conversions.
Which energy is common in the examples above?
Good! It is electrical energy.
Electrical energy is produced by ELECTRICITY.

ACTIVITY! 1

What can electricity do?

Give your teacher as many examples of the uses of electricity as you can think of. The teacher will put these on the board.
How many examples has your class thought of?
There are many more examples of uses of electricity which you might not have come across but the list shows you that electricity is a very useful source of energy.
Now do Exercise 1.

Because electricity has so many uses you cannot afford to be ignorant about electricity, more so when the Government has stated that it plans to provide electricity to all towns and villages throughout our country in the future. This Unit helps you to understand some facts about electricity.

If you are going to do any experiments with electricity you will need a source. The source you will use is shown in the picture. It is a torch CELL. The torch or radio 'batteries' you buy from shops are actually cells.

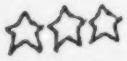
In a later unit you will learn something about how a cell produces electrical energy. You will often use more than one cell in your experiments. When more than one cell, correctly connected, is used the source of electricity is called a BATTERY.

Experiment 1 Lighting a torch bulb

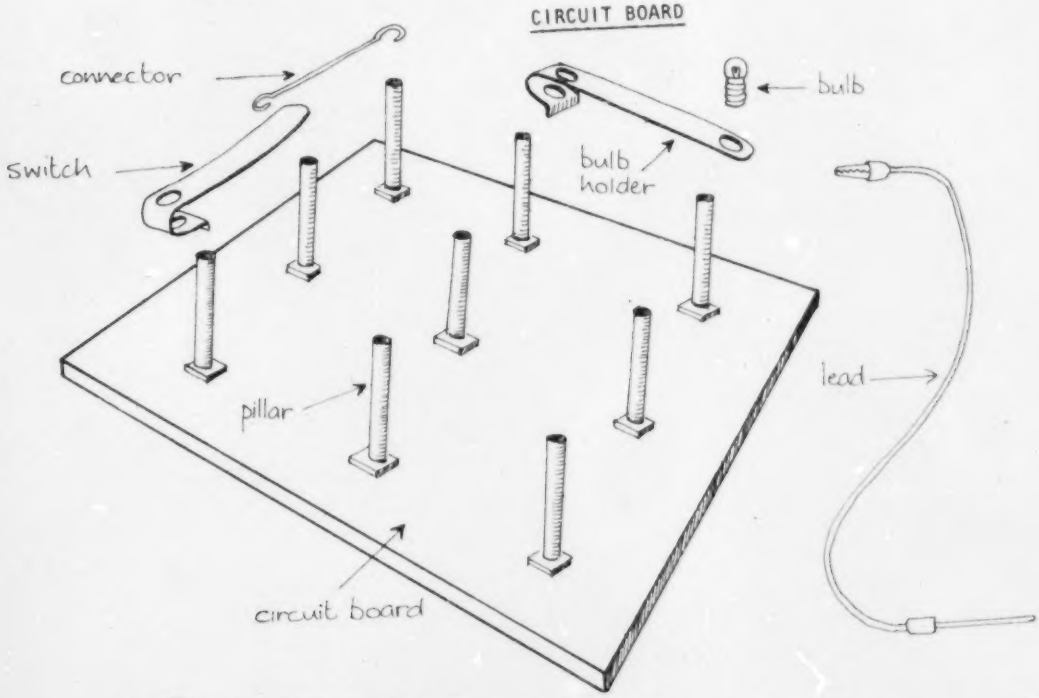
You will need:

torch cell
torch bulb
copper wire lead

Assemble the apparatus above to produce light. Call your teacher when light has been produced. Then do Exercise 2.



For electricity to produce light it needs COMPLETE PATH (WAY) to travel from the torch cell to the bulb and back again. The path is called a CIRCUIT. (Circuit means to go round.) A complete path is called a COMPLETE CIRCUIT and that which is not complete is called an INCOMPLETE OR OPEN CIRCUIT.



The circuit board is very important in studying simple circuits. Look at the diagram above and also at the circuit board and accessories you have collected from the teacher.

Experiment 2

Lighting a torch bulb using a circuit board

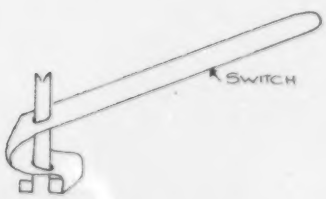
You will need:

a torch cell (in battery box)
a torch bulb
a bulb holder
a circuit board
leads (2)

Using the apparatus provided repeat Experiment 1 and light the torch bulb.

Compare your circuit with the circuit diagram in Exercise 2
What type of circuit do you need to light a bulb?
Good! A complete circuit again.
Break the circuit so that you do not waste your electrical energy unnecessarily.
Do Exercise 3

THE SWITCH



Collect a switch from your teacher. A switch is always included in the circuit.
Why? Let us find out.

Experiment 3

What is the use of a Switch in a Circuit?

You will need:

Battery Box
Leads(2)
Torch bulb and holder
A switch

Screw a torch bulb to a bulb holder.
Fix the holder to one of the pillars on the circuit board.
Make the metal part at the bottom of the bulb sit on the EDGE of the next pillar.
Fix the switch to a third pillar so that its other end is above the pillar to which the holder is fixed.
Using the leads connect the cell in a battery box to your bulb and switch.
Does the bulb glow?

What type of circuit do you have?
Make the bulb glow.

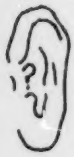
What did you do to make the bulb glow?
Remove your finger from the switch.
What now happens to the bulb?
What type of circuit do you have?
Can you now tell your teacher what the use of a switch is in a circuit?

Now do Exercise 4

CONDUCTORS AND INSULATORS

Electricity needs a complete path/circuit to flow from a cell and back.

This path was completed by the leads, the switch and the wing-nuts of the battery box.



Do different substances/materials allow electricity to flow through them?
What do you think?
Discuss this with your teacher.

Electricity is a form of energy and, as such, it cannot be seen when it flows.
What could tell us that electricity is flowing?
Think back a bit.
Does the torch bulb glow when the circuit is incomplete?
No This is what we shall use to investigate whether different materials complete the circuit and so light the bulb.

Experiment 4

Do different solid materials/substances allow electricity to pass through them?

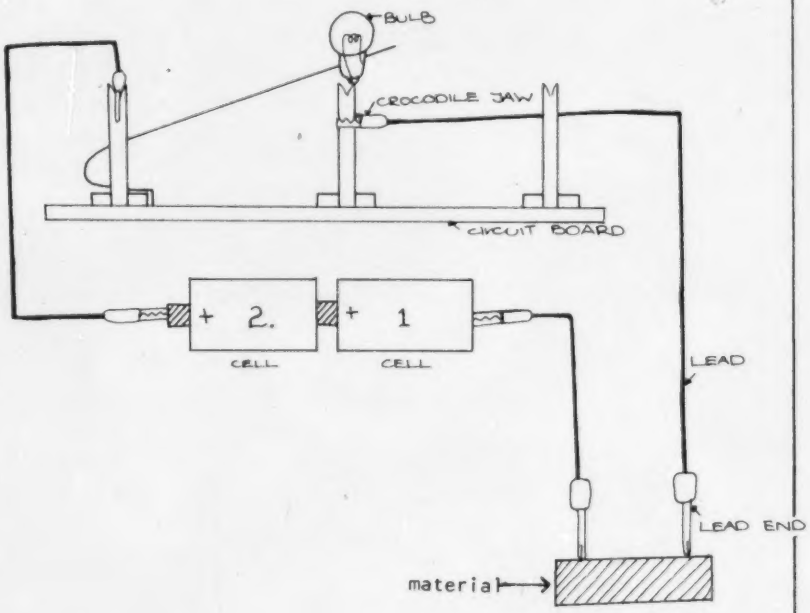
You will need:

Circuit board
Torch bulb and holder
Battery box
Leads (3)

Various materials;
materials kit:- strips of aluminium, copper iron (thin), mild steel (thick), perspex (like glass), short spring, polythene (whitish and soft), polystyrene (white cube), foam rubber (spongy cube).

Other materials:- glass, wood, grass, rubber band, carbon rod, connector (brass), plastic bag, paper clip.

First copy down into your notebook the Table which your teacher has on the board, and fill it in as you go along.
Assemble your apparatus as in the diagram below.
Do not introduce the solid material yet.



Make the lead ends touch. The bulb should glow. If not, check your connections. When the bulb glows your circuit is complete.
Separate the ends and place a material on your desk.
Touch the ends of the material as in the diagram.
What happens? Does the bulb glow?
Record your observations in the first three columns of your Table.
Remove the material and put in another one. Touch the ends of this material with the ends of your leads.
Record your observations again in the Table.
Repeat this until all the solid materials have been tested.

Before leaving this experiment you can answer another question.
Does air allow electricity to pass through it?
What did you notice when there was only air between the ends of the leads?
Write the observation into your table too.

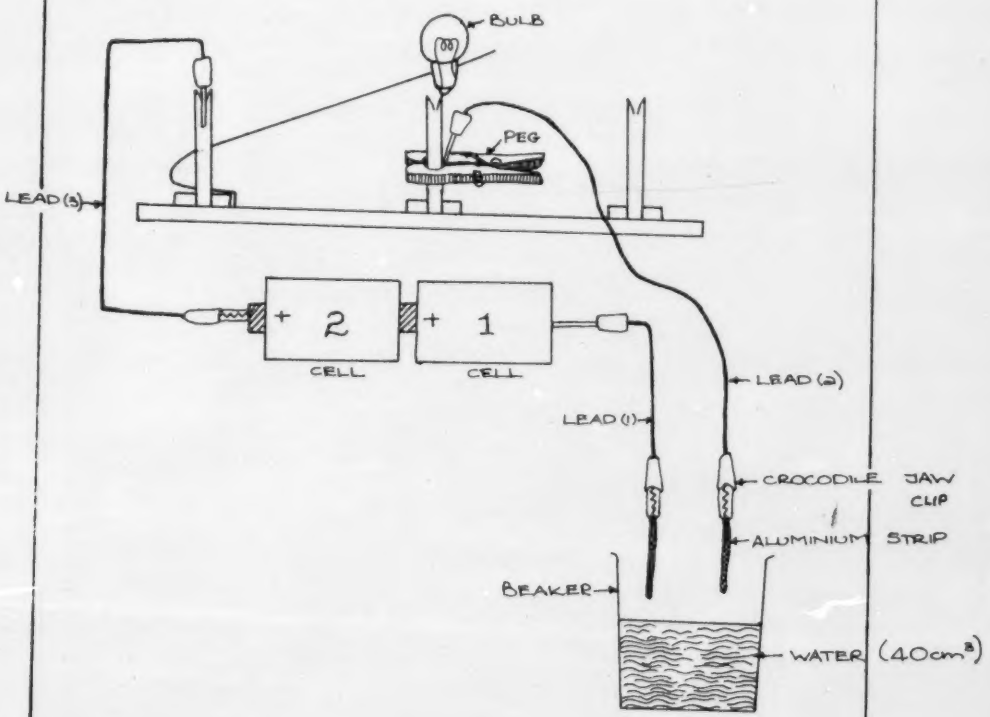
Experiment 5

Do liquids allow electricity to flow through them?

You will need:

Circuit in Experiment 4
A peg
3 leads
2 aluminium strips (2cm by 5cm long)

Liquids:- Water, salt solution, methylated spirit, hydrochloric acid, from your teacher in a graduated beaker.



Collect about $40cm^3$ of water in your beaker and place it on your desk. Hold the end of one lead (without the crocodile jaw) against a pillar by means of a peg.

Fix an aluminium strip to each crocodile jaw.
Make aluminium strips touch each other.
Why do you do that? If nothing happens what do you do next?

Check your connections.
Make them touch again. Your bulb should light now.
Separate the strips and straighten them if need be.
Lower the strips into the water in your beaker (be careful not to let the clips get wet).
What happens?
Bring your strips very close to each other without letting them touch each other.
What happens? Does water allow electricity to pass through it?
Can you now fill in your results in the table in your notebook?
Good!

Now repeat this experiment with each of the other liquids - salt solution, methylated spirits and hydrochloric acid in turn. Remember to check that your circuit is still working before each experiment by touching the leads together. Take great care when testing the hydrochloric acid. Record all your observations in the Table.

From the experiments, it is possible to classify substances into two groups - those that allow electricity to pass/flow through them and those that do not. Substances which allow electricity to pass through them are called CONDUCTORS. Substances which do not allow electricity to flow through them are called INSULATORS.

You should also have noticed that when a liquid allows electricity to pass through it there are changes in the liquid. These chemical changes which happen in liquids are very interesting but complicated effects of electrical energy and we will investigate them in a later unit.

Now go back to your Table in the note book and fill in the Column 4.

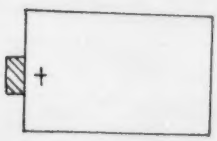
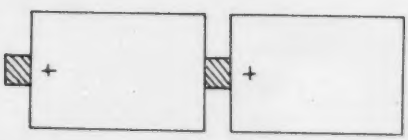
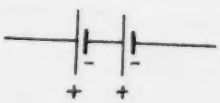
In Unit F_2 Part 2 you learnt about metals and non-metals. Remember! In Column 5 in your notebook fill in metal/non-metal for each of the substances you have used. Then complete the rest of Exercise 5 which your teacher has put on the board.

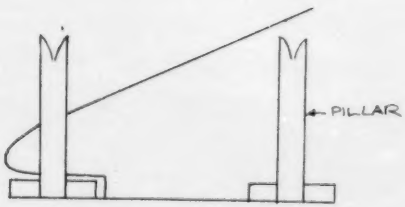
ELECTRICAL SYMBOLS

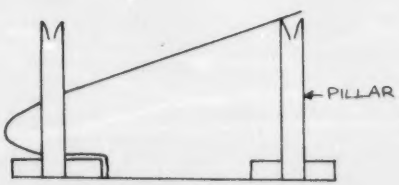
How long did it take you to draw the circuit diagram in Exercise 3 ? If you were now asked to draw diagrams in Experiments 4 and 5 how long do you think it will take you? Do you learn more science by drawing these diagrams? What do you say?

Drawing these diagrams, like the one you drew in Exercise 3 , takes a long time. In fact it wastes time - precious time you need to discover and learn exciting things in science. For this reason certain SIGNS OR SYMBOLS are used by scientists to represent the various parts of an electrical circuit.

Below are a few of the parts of the circuit and their symbols you have come across so far. More will follow as you progress.

PART	SYMBOL
	
	

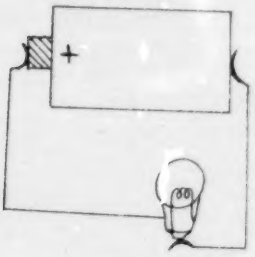


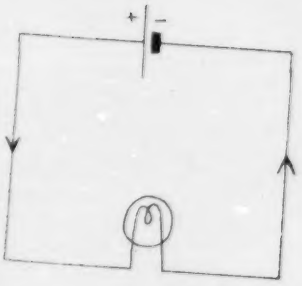


Let us now use these symbols to draw diagrams of circuits we have seen up to now.

ELECTRICAL CIRCUITS IN SYMBOLS

Lighting a torch bulb using one Cell





The circuit applies to Experiment 1 and 2. Note that the circuit board is not included. It is only the circuit we want.

DIRECTION OF FLOW OF ELECTRICITY IN A CIRCUIT

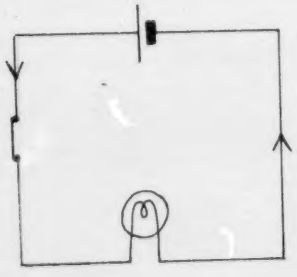
When scientists first investigated electricity they did not have any idea what it was. It seemed reasonable to see it as a flow of energy. A flow must have a direction. None of the experiments they had done told them the real direction of flow so they decided to make a rule which would allow different scientists to compare the results of experiments without becoming confused.

Look at the diagram of the cell and then at the cell your teacher has given you. Do you see a plus (+) sign? When the ends (TERMINALS) of a cell are connected by a conductor fitted with a bulb, the bulb glows meaning that the circuit is complete. The rule we use is that when the circuit is complete electricity from the cell flows from the plus terminal to the negative terminal. The plus terminal is called the POSITIVE terminal. Thus in a complete circuit electricity flows from a positive (+ ve) terminal to a negative (- VE) terminal.

Look at the circuit of lighting the torch bulb again.
Do you see arrows? Good!
Look at the symbol for the cell.
The long vertical line (|) is the symbol for the positive terminal and the short one (▮) is the symbol for the negative terminal. Remember this!
It is not necessary to put a plus or minus sign above or near these lines when drawing the symbol of a cell.

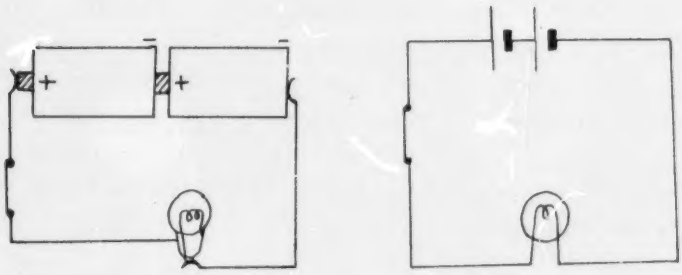
Here are some more circuits for the experiments you have done so far!

Completing a torch bulb circuit by means of a switch

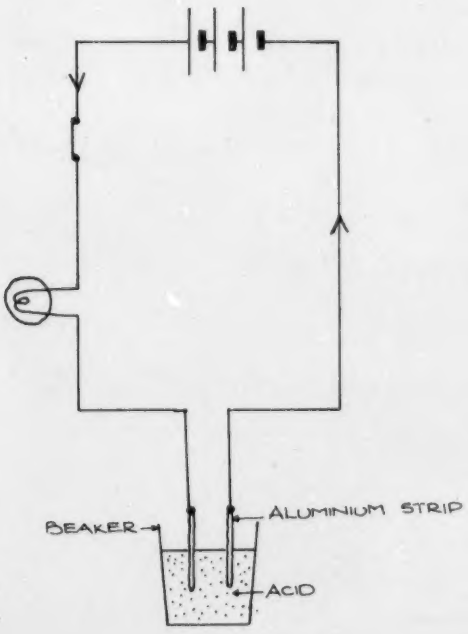


Note again that the circuit board does not appear in circuit

Lighting a torch bulb using two cells



Circuit on Conduction of Electricity through Hydrochloric Acid



Which method of drawing circuits is easier and quicker?

Now do Exercise 6 , which your teacher has put on the board for you.

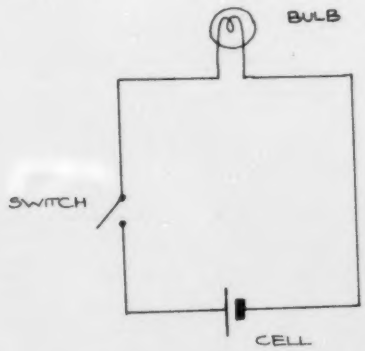
Experiment 6

CONNECTING CELLS IN CIRCUITS

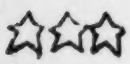
In Experiment 2 you used one cell to light a torch bulb.
How bright was the torch bulb, do you remember?
Let us quickly carry out that experiment once more, this time noting the brightness of the bulb.

You will need:

Battery box
Circuit board
A switch
Leads (2)
Torch bulb and holder

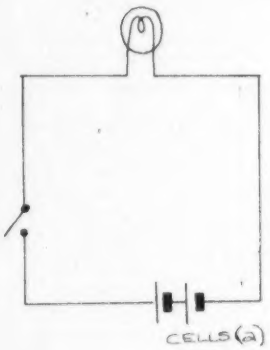


Connect your apparatus on the circuit board as in the circuit above. Use only one cell in the circuit. Complete the circuit. What happens to the bulb?
If nothing happens what does this tell you about your circuit? Check your circuit again until your bulb lights. Note carefully the brightness of your bulb. This is the amount of light energy produced in the bulb by one cell.



The bulb is an example of an energy changer, it changes electrical energy to heat and light energy.

Let us now try to light the same bulb using two cells connected end to end.

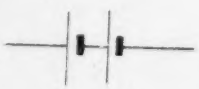


Use the same apparatus as before but instead of one cell use two in the circuit. Connect them end to end as in the diagram above. Complete the circuit.
What happens to the bulb? Is the brightness the same as in the first circuit of this experiment?
What does this suggest about the amount of energy released in the bulb by these cells connected end to end?

When the cells are connected end to end, that is the positive terminal of one cell is connected to the negative terminal (back) of the next cell we say the cells are connected IN SERIES.

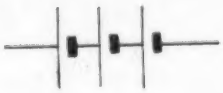
CELLS IN SERIES

(1) Two cells connected in series

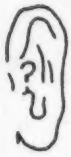


These two form a battery of two cells.

(2) Battery of three cells



A battery of three cells contains more electrical ENERGY than the one with two cells. A battery of two cells contains more electrical energy than one of one cell.



The brightness of the bulb tells you something about the amount of electrical energy being changed to heat and light in it. What do you think then is the effect of connecting cells in series to a single bulb?
Discuss this with your teacher.

Lighting more than one torch bulb

So far we have been experimenting by lighting one bulb (in the previous experiments) using one or two cells in the circuit. Can we use our battery (2 cells) to light two bulbs?
What do you think? Can you do it?

Experiment 7

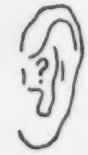
Lighting two bulbs using a battery

You will need:

Circuit board
Battery box
Two leads
Two bulbs and their holders
A switch
A connector (if you think you need one)

Try to assemble the circuit on your own.
Complete the circuit. Do your bulbs light?
If nothing happens QUICKLY SWITCH OFF!
Check your connections and trace the path of your electricity.
Perhaps your circuit is not complete. Switch on again and if nothing happens it may be that the electricity is flowing through another part of the circuit which leaves the bulbs out.
When you are REALLY STUCK call your teacher for hints.
Keep trying until both bulbs light. Then call your teacher again and show him/her your circuit.
Complete your circuit again to light the bulbs.
While the bulbs glow lift one of the bulbs so that it does not rest on a pillar. What happens to the other bulb?
Think carefully about what you observe. Let the bulb rest on the pillar again. What happens?
Lift the other bulb, what happens to the first one?
Why is this so?
Let the bulb sit on the pillar. Do both bulbs light?
Good! Now look at the brightness of the two bulbs.
Is the brightness of each bulb greater than the brightness of the bulb in the second circuit of Experiment 6.

Can you light the same bulbs in a different arrangement from your first one above without adding any extra apparatus? Try.
There are at least two ways but if you can do more in the time set aside by your teacher well and good.
Do not forget to lift your bulbs separately and note what happens to the other one which rests on the pillar.



Break each circuit when you have finished observing.
Try to draw each of the successful circuits in your notebook.
Discuss your circuits with the teacher.
Complete Exercise 7 which is on the board.

☆☆☆ When the same electrical flow passes through two or more bulbs we say that the bulbs are connected in SERIES. When one bulb goes off in a series circuit, the other(s) go off too because the circuit is broken at that point.

Torch bulbs in Parallel

You have just discovered that two bulbs connected in series will light as long as the circuit is complete. If one bulb were removed the remaining bulb would go off since the circuit is now incomplete.
Is there a way of lighting the same two bulbs so that when one is removed or goes off the other one will still remain glowing?
This is your problem. Try to solve it. It can be done.

Experiment 8

To light two bulbs so that when one is removed the other one remains glowing.

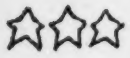
You will need:

Battery (2 cells)
Connectors
Bulbs and their holders (2)
A switch
Leads (2)

Using the apparatus above try to set up the circuit.
Check your circuit and then switch on. Do the bulbs light up?

When you have succeeded in making both bulbs light up, lift one bulb. What happens to the other bulb?
Let the bulb rest on the edge of the pillar again.
Lift the other bulb and note what happens to the one you lifted first.

Let it rest on the edge of the pillar again so that both bulbs glow. Compare the brightness of these two bulbs with the brightness of the same bulbs in the series circuit.
Which arrangement produces more light in the bulbs, this one or the series one?
Can you explain why one bulb remains glowing brightly when the other one is lifted?
What do you think happens to electricity as it enters and leaves that part of the circuit with bulbs?

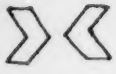


When two or more bulbs are connected in this way (side by side) we say they are connected in PARALLEL. In a PARALLEL circuit electricity divides so that part of it flows through each bulb and join up again before flowing back to the battery. This is why one bulb remains glowing brightly when the other one is removed. Bulbs in a parallel circuit are much brighter than the same bulbs in a series circuit. This means that bulbs in a parallel circuit change more energy from electrical to heat and light than the same bulbs in a series circuit.

Now do exercise 8

<u>WHAT WE HAVE LEARNT SO FAR</u>:

What have we learnt so far about electricity?
We now know that:



(1) a cell or battery is a source of electrical energy.
(2) for electricity to flow a complete circuit is required.
(3) a torch bulb in a complete circuit converts electrical energy to heat and light energy.
(4) In a series circuit the same electrical flow delivers energy to both bulbs and when one bulb is removed the circuit is broken i.e. no electrical flow - therefore no energy delivered to the other bulb.

(5) In a parallel circuit the main electrical flow divides so that part of it flows through each bulb delivering more energy (bulbs are brighter than the same bulbs in series) and combine again before flowing back to the cell or battery. When one bulb is removed the other one continues to receive energy.

MEASUREMENT OF ELECTRIC CURRENT

We have talked about the "flow of electricity" in the work you have done so far. We have also talked about the energy which that flow carries and which is changed into heat and light in a bulb. We could roughly measure the flow by the amount of energy which it delivers. In other words by the brightness of the bulb.

This means that the light produced by one bulb when connected to a cell is "one light bulb unit" and it is "two light bulb units" when two cells (battery) are used. In which circuit does a bulb glow brighter?

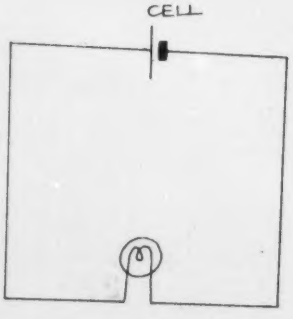
Experiment 9

To find out in which circuit a bulb glows brighter.

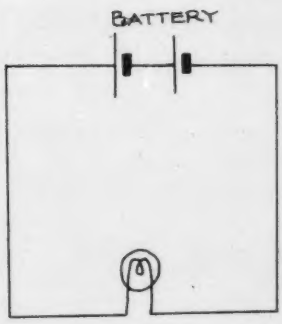
You will need:

a circuit board
a bulb and holder
leads (2)
a battery box

(a)



(b)



Quickly set up the circuit in (a) above. Note the brightness of the bulb. This is "light bulb one" or "unit one".
Now include two cells in your circuit as in (b).
Is your bulb brighter, less bright, or the same as in (a)?
How many units are these?

Two of course.

In which circuit is more electricity flowing through?

The "light bulb units" are a rough measure of electrical flow. This is so because when two cells were used the bulb glowed twice as bright as when one cell was used. This suggests that the electrical flow was doubled.

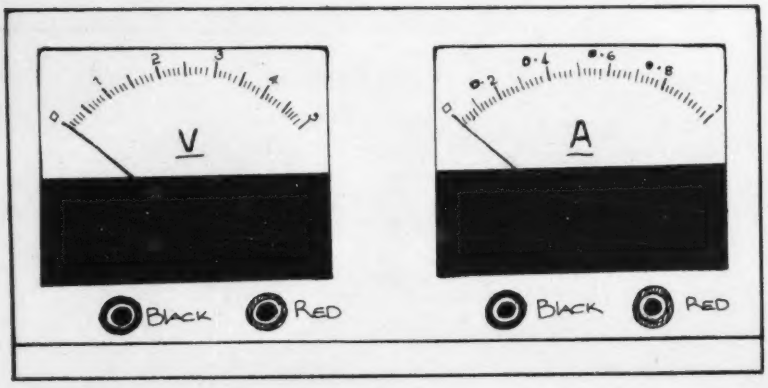
As scientists we need to be more accurate than this. Let us find out how electrical flow is measured.

ACTIVITY 2

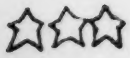
Looking at the electrical flow measurer - the Ammeter

You will need:

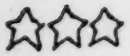
The ammeter



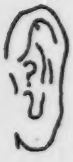
There are two instruments fitted to this box. The "V"-instrument on one side and the "A"-instrument on the other. Both these instruments are very delicate. Be very careful when using them.



The instrument we want at the moment is that marked 'A'. The flow of electricity is called CURRENT. In every day life we talk of water currents and this means running water or flowing water. From now on we are going to talk about electric CURRENT/S.



The instrument used to measure currents is called an AMMETER. The unit of current is an AMPERE (A).



Look at the ammeter. What is the lowest current you can measure on this instrument? What maximum current can you measure on this ammeter? What does EACH GRADUATION on this scale represent?
Discuss this with your teacher.

☆☆☆ This ammeter measures currents between 0-1 amperes (A) and each graduation represents 0,02 A. The ammeter is quite accurate

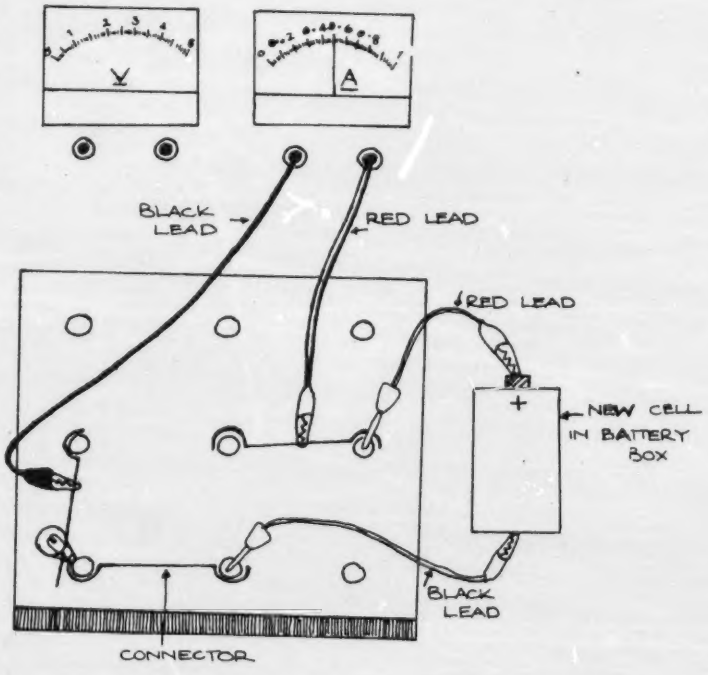
CONNECTING AN AMMETER TO A CIRCUIT

Experiment 10

Investigating electrical current flow

For this experiment you will need:

circuit board
bulb and holder
battery box
2 thick leads (red and black) for ammeter
2 thin leads (red and black)

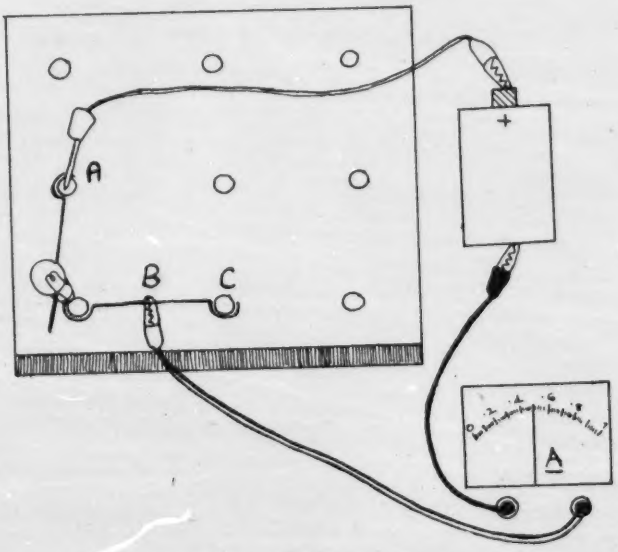


Part 1

Study the diagram above carefully and then assemble your circuit.
Does the bulb glow? What do you notice on the ammeter?
Note the reading. Lift the bulb.
What happens to the reading on the ammeter?
What does this mean?
How is the ammeter connected in the circuit?
Remember series and parallel connections!
Do not leave your circuit complete for a long time lest you discharge your cell too quickly.
Break your circuit as soon as possible to conserve electrical energy.

Part 2

The diagram below shows the ammeter in a different position to that in Part 1. Look at it carefully and then set up this circuit with the ammeter correctly connected.
Complete the circuit. Take the ammeter reading and disconnect at ends A and B.
Proceed to Part 3 of this Experiment.



Part 3

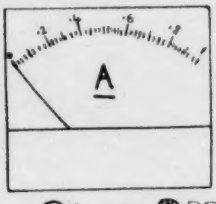
Using the diagram in Part 2, plug end A into pillar C.
Pick up the red lead of the ammeter. While looking at the ammeter briefly touch , with end B, the pillar where end A was plugged in and quickly disconnect.
Which way did the pointer move?
N.B. Tap the ammeter gently if the pointer fails to return to zero.
Discuss your observations with your teacher and then complete the first part of Exercise 9

The current in a circuit flows in a definite direction.
Remember we said scientists decided it flows from the positive terminal (+ ve) to the negative (- ve) terminal.
A current which flows in ONE direction is called DIRECT CURRENT (D.C.). The ammeter is made in such a way that it can only measure currents when it is CORRECTLY CONNECTED.
The correct connections are: RED leads are connected to the POSITIVE TERMINAL and the BLACK leads are connected to the NEGATIVE TERMINAL.

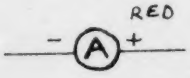
SYMBOL FOR THE AMMETER

The ammeter has this symbol.

AMMETER



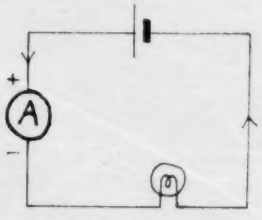
SYMBOL



The (+) and (-) signs do not mean that the ammeter is a source of electrical energy. They are to help you connect the ammeter correctly to a circuit.

DRAWING A CIRCUIT INCLUDING AN AMMETER IN SYMBOLS

We have already seen that it is easier to draw circuits in symbols rather than draw the same circuits in drawings. Let us draw the circuit of Experiment 10 in symbols.



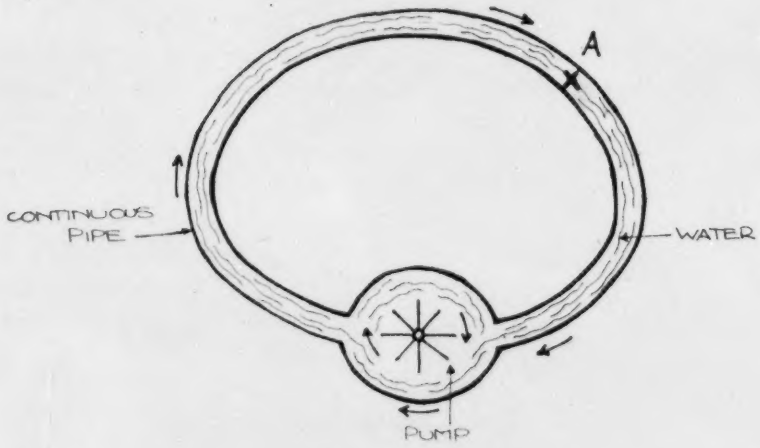
Note that the leads, connectors and bulb holder are conductors represented by a straight line. This circuit diagram shows more clearly that the ammeter is in series with the bulb.

Answer the last question in Exercise 9 .

WHAT IS IT THAT FLOWS THROUGH THE CIRCUIT?

I am sure you have been wondering what it is that flows through a complete circuit. At this stage we cannot answer that but it could be some kind of "fluid" travelling in a wire or it might be a movement of tiny "particles".

The flow of "fluid" or "particles" in a wire behaves rather like a flow of water driven by a pump round a continuous pipe.



If one litre (1 L) of water passes a certain point, say A, in the pipe in one second (1 s), then the flow will be one litre per second (1 L/s) at every other point in the pipe.
What corresponds to the pump, pipe and water in an electric circuit?
Would you place your water meter in series or parallel to the continuous pipe to measure the water flow?

Experiment 11

MEASURING CURRENT IN MORE COMPLICATED CIRCUITS

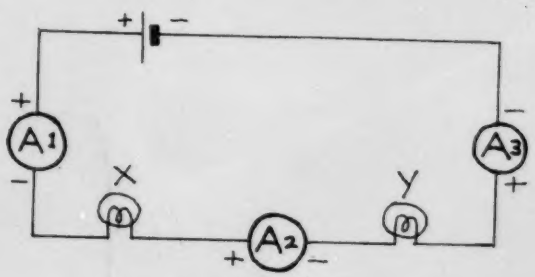
By now you are familiar with a series circuit. If you have forgotten quickly refer to Experiment 7 in this Unit.
All that you have to do is to read the circuit diagram very carefully and then set up the circuit and take ammeter readings. Do you think you can do this?

Before assembling the first circuit in this experiment draw the table which your teacher has put on the board in your notebook.

You will need:

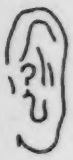
Circuit board
Leads
Ammeter
Two bulbs and holders
Connectors
Battery box

Circuit No 1

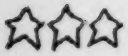


Assemble the circuit above with the ammeter in position A_1.

A_1 means the ammeter is placed between the cell and bulb X.
A_2 is placed between X and Y and A_3 between Y and the cell.
Be careful about your ammeter connections.
At each ammeter position take the ammeter reading and note the brightness of the bulbs.
Then lift one bulb.
What happens to the ammeter reading and the other bulb?
What type of circuit do you now have?



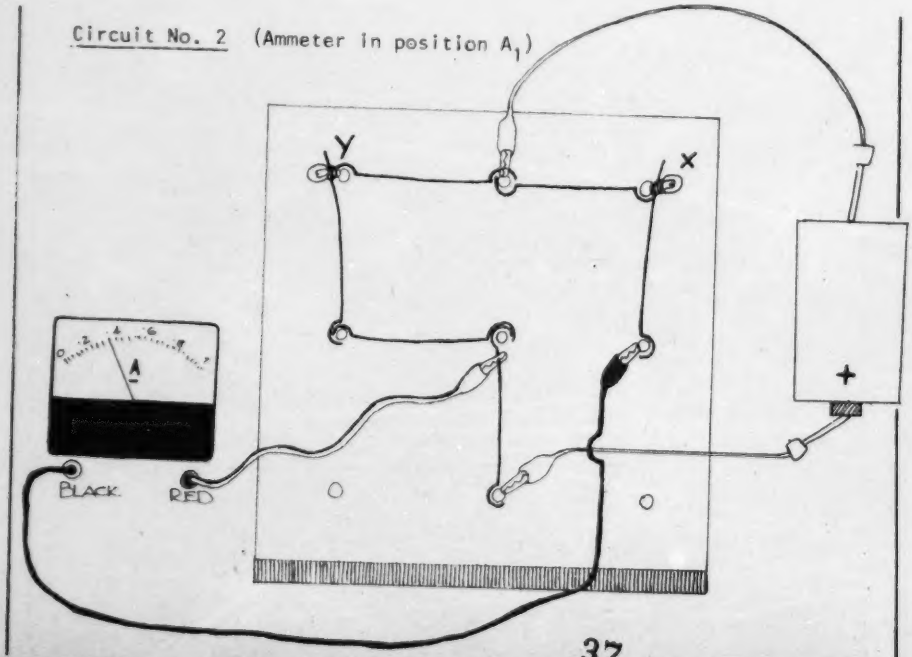
Next re-arrange your circuit so that only bulb X is in the circuit.
Is the light energy produced by X more or less than that produced by X and Y in series?
Why is this so? Discuss this with your teacher.



Electrical energy from the cell is converted into light energy in the bulb/s. When one bulb (X) is used it glows brighter than two bulbs (X and Y) in series. This means that the bulbs in series share the energy produced by the cell. This is why the two bulbs are dimmer.

Now answer the first part of Exercise 10.

Circuit No. 2 (Ammeter in position A_1)



In Experiment 8 you set up a parallel circuit like this one to light two bulbs.

Remember the experiment? How bright were the bulbs compared to the same bulbs in the series?

From the brightness of the bulbs can you suggest anything about the flow of current?

Let us find out whether your theory is correct.

Set up the circuit above and complete the circuit.

What happens to the bulbs?

How bright are they compared to the same bulbs in series?

Take the ammeter reading. Does the ammeter in this position A_1 measure the current flowing through both bulbs or only one of them?

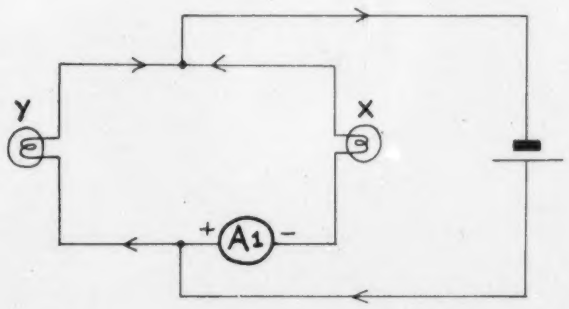
If one of them, which one?

Lift Y. What happens?

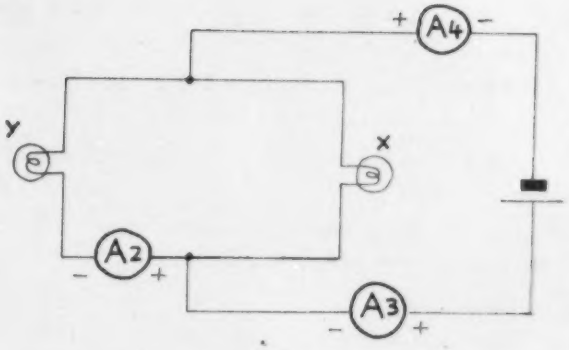
Is there a change in the ammeter reading?

Break the circuit.

The circuit you now have can be drawn easily in symbols.



Next I would like you to re-arrange your circuit so that you can measure the current flowing through the ammeter in positions A_2, A_3, and A_4 in the circuit below. Be careful about your ammeter connections.



(1) AMMETER IN POSITION A_2

Take the ammeter reading. Then lift bulb X.
What is the ammeter reading this time?
Is there any change in current and brightness of bulb Y?

(2) AMMETER IN POSITION A_3

Take the reading of A_3. Lift X.
What is the reading this time?
Compare this reading with that of A_2.
Return X to the pillar. Lift Y.
What is the reading?
Compare this reading with that of A_1.

(3) AMMETER IN POSITION A_4

Take the reading of A_4 when the circuit is complete.
To which ammeter reading is this reading equal?

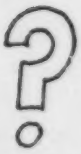
After taking the reading of A_4, break the circuit and answer the last questions of Exercise 10

Discuss the results of all your investigations with your teacher.

In Experiment 6 you lit one bulb using one and the two cells.

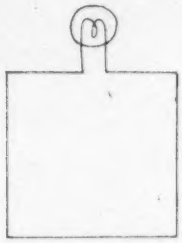
Do you still remember which circuit produced more energy (light)?
Good! It was the circuit with two cells in series.
What about the current, which circuit do you think has more current flowing through it?
You can guess, but that is not good enough.
Repeat the experiment this time using two cells and compare your results.

HOW MUCH DO YOU KNOW? (1)



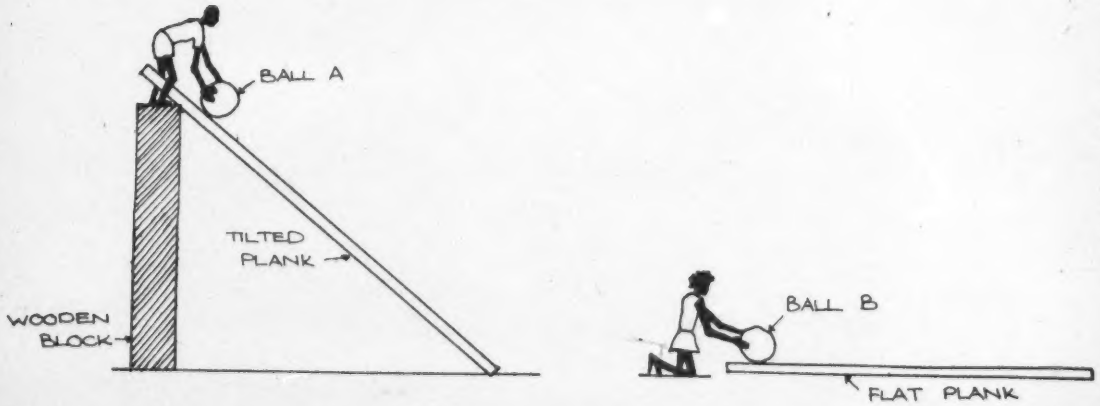
1. An electric current can only flow when there is a _____ circuit.
2. The unit of current is an _____ whose symbol is _____ and is measured by an _____ which is connected in _____ with the circuit.
3. The _____ is not used up when it flows through the circuit. What is 'used up' is the _____ it delivers as it flows through the circuit.
4. The current flowing through a _____ circuit is the _____ same at _____ _____ end of the circuit.
5. In a series circuit the _____ is shared by the energy changers in it.
6. In a _____ circuit the _____ current is divided into _____ or more branches. The branch currents _____ up to make the _____ in the circuit.
7. When a bulb in a parallel circuit goes off the other bulbs will _____ since their _____ are still _____
   For this reason _____ in homes are connected in _____.
8. More current flows through a _____ circuit than a _____ circuit. When the energy source (number of cells) is unchanged. For this reason bulbs in a _____ circuit are _____ than the same bulbs in a _____ since a large current delivers more _____.
9. Electric bulbs convert _____ energy into _____ energy.

What makes things happen in an electrical circuit?



Look at the circuit diagram above.
What kind of circuit is it?
Will the bulb in this circuit glow?
Why will it not glow since the circuit is complete?
The bulb will not glow because there is no SOURCE of electric energy - a cell or battery. This suggests that a cell or battery possesses POTENTIAL ENERGY which when properly connected is converted to electrical energy which, in turn, is converted to light and heat energy. This does not completely answer the question "What makes things happen in an electrical circuit?" but let's first review what we know about energy before trying to answer the question.

In Unit B you learnt a lot about energy and energy conversions.
Do you still remember potential energy?
Good! Now look at the diagram below.



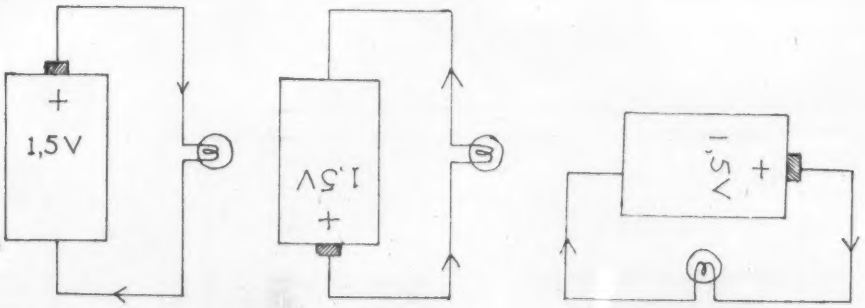
Jabulani holds a ball at the top of the tilted plank.
Faral holds a ball on one end of a level plank.
What happens when both let go?

For a ball to move on its own there must be a DIFFERENCE in height between the ends of the plank. If there is no DIFFERENCE then there is no movement.

If you remember your work from Unit B you will know that we are talking about a difference in potential energy.

What would Jabulani do to make the ball on the plank roll faster?
Good! He would increase the potential energy difference by tilting the plank more!

Similarly, for electric current to flow through a circuit there should be sufficient POTENTIAL ENERGY DIFFERENCE between the positive and negative terminals of a cell or a battery. It is this potential energy difference (usually shortened to potential difference) which makes things happen in an electrical circuit. The position (up, down and sideways) of the cell does not affect the direction of flow of the current of course! The energy does not come from gravity but from a chemical reaction.



As the cell or battery supplies electrical energy to light up a bulb the chemicals in it get used up. This causes the potential difference (p.d.) to drop and hence less energy (heat and light) is available.

When the cell or battery is flat it means the chemicals have been used up so there will be very little or no potential difference between the terminals, no available energy.

UNIT OF AVAILABLE ELECTRICAL ENERGY

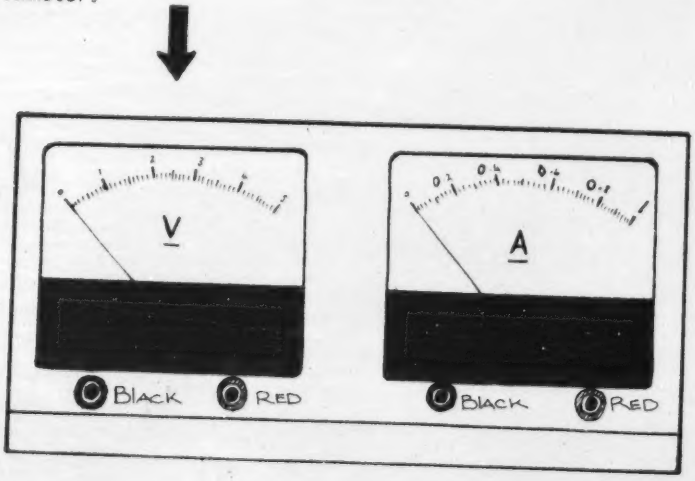
☆☆☆

Available electrical energy which is carried by the current in a circuit is measured in VOLTS (V). POTENTIAL DIFFERENCE we talked about above is measured in volts. Look at your cell.
What voltage is marked on it?
Good! It is 1,5 V.
Let us now turn to the measurement of voltage.

INSTRUMENT FOR MEASURING AVAILABLE ELECTRICAL ENERGY (- VOLTAGE)

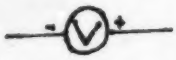
You will need

A VOLTMETER
This is the other instrument in the case which contains the Ammeter.



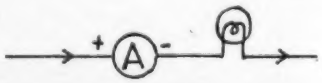
A VOLTMETER is used to measure VOLTAGE - available energy.
Look at your voltmeter marked '_'.
What is the maximum number of volts you can measure with this instrument?
What does EACH graduation on the voltmeter represent?
Do you see RED and BLACK sockets (holes)?
Through which socket does electricity flow in?
Good! It is through the red socket.
Now let us use the voltmeter to measure voltages of cells.

Symbol of Voltmeter

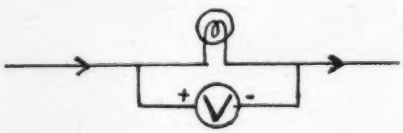


How is a Voltmeter connected in the Circuit?

An ammeter, as you already know, is connected in series in the circuit.



A voltmeter ( ) because it measures the potential difference (p.d.) across a part of the circuit is connected PARALLEL to the circuit.



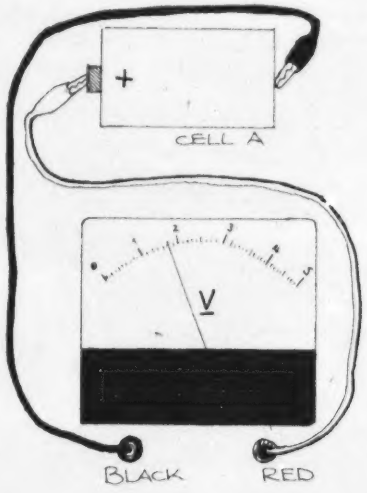
In the part of a circuit shown in the diagram the voltmeter is measuring the potential difference across the bulb.
This potential difference is a measure of the energy being changed into heat and light as the current goes through the very thin wire inside the bulb.

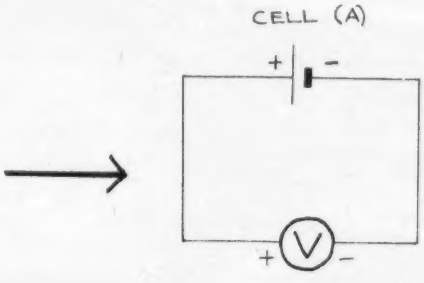
Experiment 12

MEASURING VOLTAGES OF 1, 2, 3 NEW CELLS

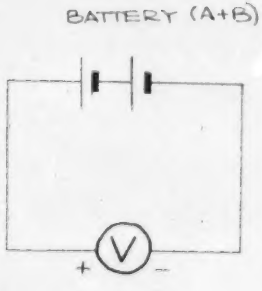
You will need:

3 new cells
a Voltmeter
leads (red and black) which fit in the sockets of the voltmeter battery box

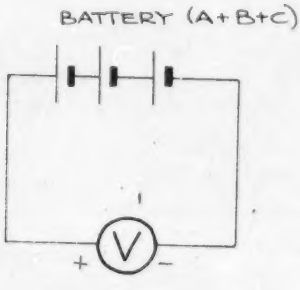




(a)



(b)

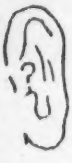


(c)

Collect three new cells from you teacher and call them A, B and C.
Plug your red and black leads into the voltmeter sockets.
Touch the ends (terminals) of cell A as in the diagram above.
What is the reading?
Next proceed to measure, separately, the voltages of cell B and C.
Note the reading in each case.
Compare your readings with the voltage marked on each cell.
Are your cells new or have they been used?
If the reading is less than the one marked, then the cell has been used or old

Copy the table of Exercise 11 and fill in your measurements.

Next put the cells in the battery-box, starting with A on the right.
Now connect your voltmeter to two cells (A + B) as in (b) above.
Take the reading and write it in the Table.
Finally include three cells (A, B and C) in your circuit as in (c).
Take the reading and record it again.
Disconnect and answer Question 2.



Do you now see why a bulb connected to two/three cells glows brighter?
Discuss these thoughts with your teacher.

In the previous experiment you measured the **available** energy which can be converted to other forms of energy. Available energy (measured in volts) is the voltage you get when you connect the ends (terminals) of a cell or battery to a voltmeter, when the cell or battery is not working.
What was the voltages in Experiment 12 (a), (b) and (c)?
This is the available energy produced by the cell or battery.
What happens to the energy when bulbs are connected to the cells?
Let us measure the voltage at different parts of a circuit.

TRACING ENERGY CHANGES IN A CIRCUIT

For work to be done in any part of a circuit energy is needed. Examples are:
you need energy to drive the current through the circuit;
you need energy to convert into light and heat in a bulb or bulbs etc. This energy is supplied by a cell/battery.
Measurement of potential difference (volts) across different parts of the circuit tells us how much energy is needed to drive the current through that part of the circuit or how much energy is converted into other forms of energy e.g. heat and light in that part of the circuit.
Let us now measure voltages across different parts of a circuit.

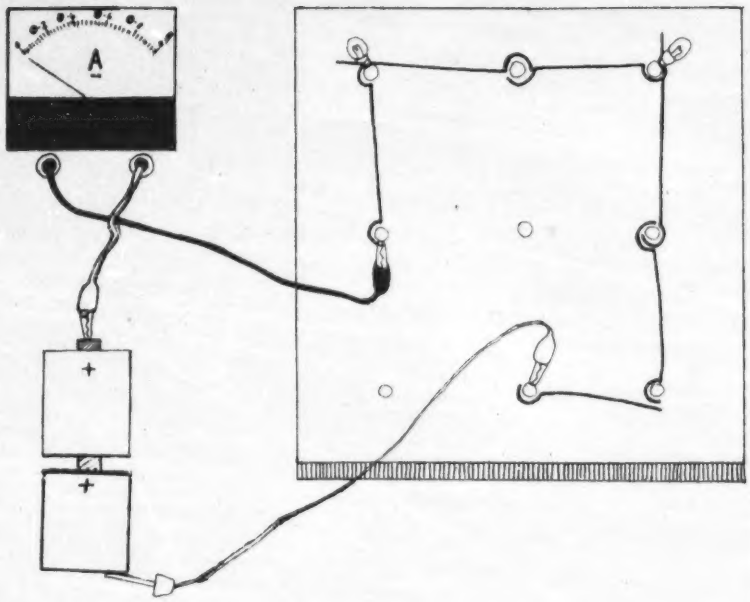
Experiment 13

To trace energy change in different parts of a circuit using a Voltmeter

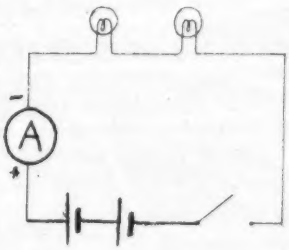
You will need:

Voltmeter and an ammeter
Two new cells (if available) in battery box
Two torch bulbs
Circuit board
A switch
Leads (5)
Connectors (3)

Place your circuit board on the desk and then assemble your apparatus as in the diagram below.



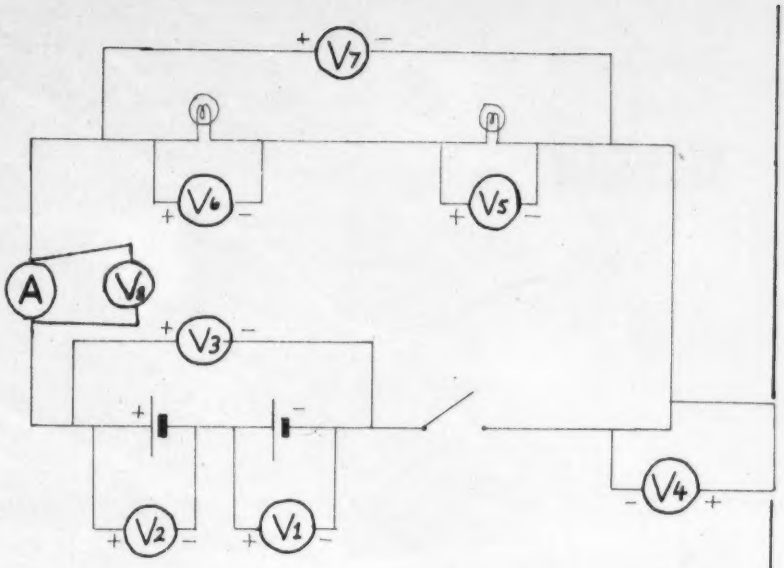
In symbols the same circuit looks like this:-



Switch on. Do your bulbs glow?
If not, check your connections and switch on again.
Do they now glow?
Good! What type of circuit do you now have?

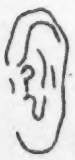
Before you proceed write down the heading of Exercise 12 and do question 1 (a) and (b).

Then take the leads of your voltmeter and clip them <u>across</u> the first cell as in the circuit below.
Remember to connect correctly.



Switch on.
Take the reading of V_1 and write it down in your book.
Remove the clips and connect them across the second cell.
Switch on, take the reading of V_2 and record it down.
Repeat the same process for V_3, V_5, V_6, V_7.
For V_4 clip on to the ends of a connector.
Switch on and take the reading.
For V_8 clip on to the metal parts of the plugs of the ammeter.
This can be done by pulling the plugs out a little.
Switch on.
What reading is shown on the voltmeter?
Switch off and do the rest of Exercise 12

Did the voltages you measured add up to the total available energy from two cells which you measured in Experiment 12 ?
Where do you think the "missing" available energy was used?
Discuss this with your teacher.

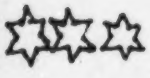


DIFFERENT SOURCES OF ELECTRICAL ENERGY

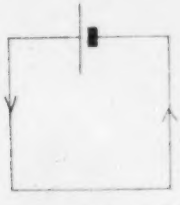
Not all sources of electrical energy are equally efficient. Some sources, such as ordinary cells are inefficient sources because they need lots of their energy to drive the current through themselves!
The car battery or accumulator does not use very much energy to drive internally the current through itself and is an efficient source.

SHORT CIRCUIT

Have you ever heard people talk of a "short" circuit?
What do they mean?



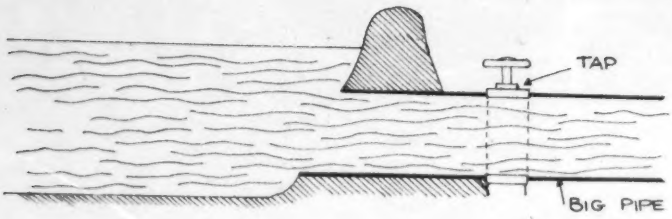
A short circuit happens when the terminals of a cell or other source of electrical energy are connected by a GOOD CONDUCTOR of electricity such as copper, brass, wire without a bulb or bulbs.



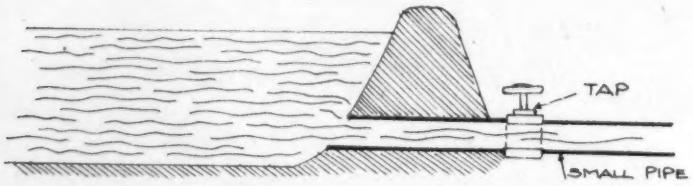
SHORT CIRCUIT

This causes a large current to flow through the wire and all the available energy flows out of the cell quickly.
As a result the wire and the cell get hot and the cell becomes <u>flat</u> or "dead" quickly.

Let me explain this in another way.

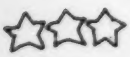


Imagine a dam full of water which has a big pipe closed by a tap. When the tap is fully opened all the water will flow out very fast in a short time and soon the dam will run dry. This is similar to a "short". Copper wire behaves like the big tap fully opened.



If the tap is only a little open or is a small tap, a small amount of water flows out at a time. To empty the dam, will take a long time.

Bulbs act as small taps and energy flows from the cell in small amounts. With this in mind NEVER SHORT-CIRCUIT a cell or a battery.



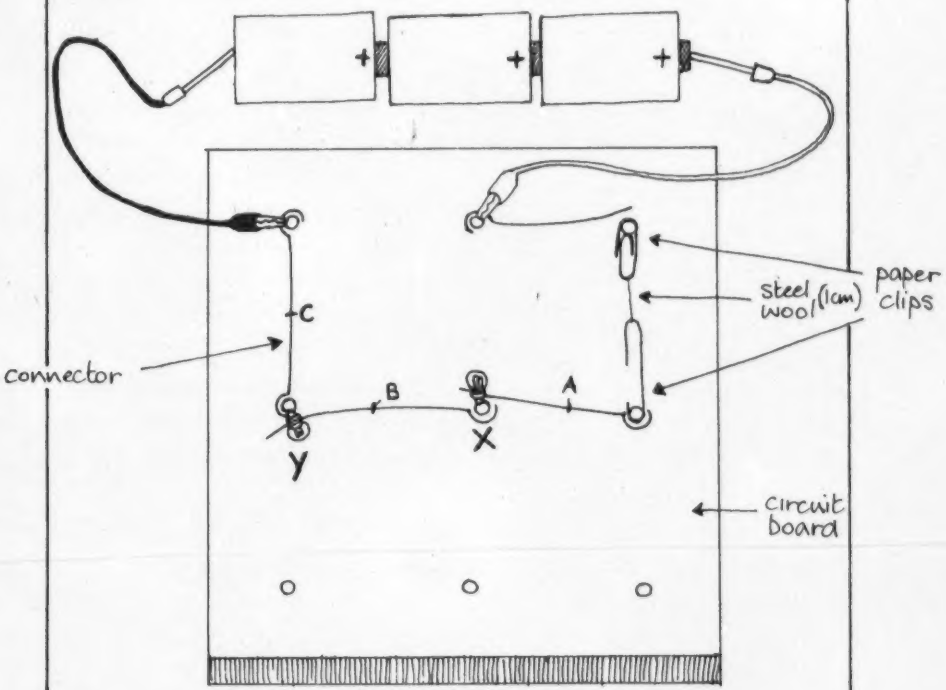
A "short" in a house that uses electricity may make the wires so hot as to cause a fire which destroys the house.
Your teacher will demonstrate this to you.

Experiment 14

Investigating Short Circuits

You will need:

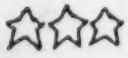
circuit board
3 cells in battery box
2 torch bulbs and holders
3 leads (one extra from the ammeter or voltmeter)
2 paper clips
1 piece of thin steel wool (about 10cm)
1 connector



Take two paper clips.
Stretch one as in the diagram above.
Fix both to the pillars of the circuit board.
Connect their loops together by tying a piece of steel wool between them. (Make sure that the contacts are firm.)
Now connect the rest of the circuit as in the diagram above.
Switch on.
What happens to bulbs X and Y?
Good! They glow brightly.
Switch off.

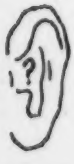
We are now going to introduce a short circuit.
Connect the extra lead between points A and B.
Think carefully about the paths available to the current when you switch on.
Will bulb X light?
Is bulb Y brighter than before?
Will the current be bigger than before?
Close the switch and observe what happens.
Switch off. Disconnect the extra lead at point B.
Now connect the extra lead between points A and C.
Will both bulbs light?
Will the current be bigger than before? Close the switch.
What happens to the piece of steel wool?
Now answer Exercise 13 .

In this experiment a large current flowed when the circuit was short circuited. This might have damaged the wires and would certainly have caused the battery to become flat very quickly if this piece of wire had not melted and acted as a switch to stop the current flowing.

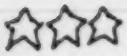


A piece of this wire used in this way in an electrical circuit is called a FUSE.

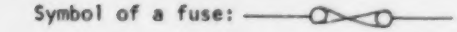
Your teacher is going to demonstrate the action of a 5A fuse wire using the rechargeable battery, so move to his table for this demonstration.



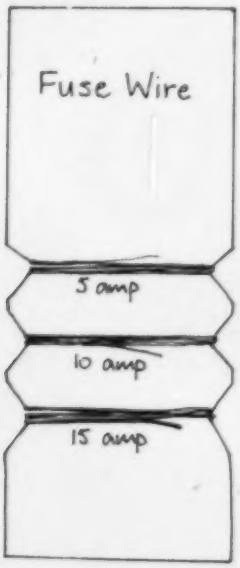
What happened to the fuse wire when the circuit was completed?
Was the current flowing through the wire greater or smaller than 5A?
Discuss this with your teacher.



A fuse wire is made of a metal which easily melts so that if the current becomes too high and the wire becomes hot, it melts and breaks the circuit. It is used to prevent <u>over-heating</u> of cables and electrical appliances.

Symbol of a fuse: 

<u>Activity 3 LOOKING AT FUSE WIRES</u>



Get a card with 5A, 10A and 15A wires wound around it from your teacher.
Stretch a piece of each wire. Look at the thickness of the wires.
Which is the thinnest and which is the thickest?

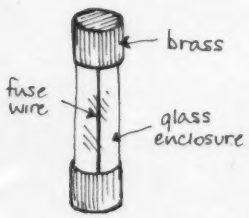
A big current needs a thick fuse wire and a small current needs a thin fuse wire.
Which fuse wire would you use in a) lighting
b) power circuits?

THE CARTRIDGE FUSE

One of the most convenient and common forms of fuses is that where the thin wire is contained in a small insulating tube. This form is called a CARTRIDGE fuse.

The diagram below shows a cartridge fuse. It consists of a short length of wire enclosed in a tube made of glass or clay. The tube is closed at both ends with metal caps e.g. brass.

Activity 4 LOOKING AT CARTRIDGE FUSES



cartridge fuse.

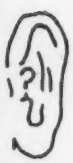
Take your ammeter/voltmeter. Look at the back of the instruments.
What do you see?
Unscrew the cap of the ammeter fuse and pull it out.
What do you see?
Pull out the cartridge fuse.
Do you see the metal caps at the ends of the glass tube?
What do you see inside the glass?
Look very carefully.
Can you see the numbers written on one of the caps?
What is its ampere rating?
What instrument is protected by this fuse?
Fit the fuse to the cap and screw the cap back.
Do the same with the voltmeter fuse.

Now answer questions on Exercise 14.

What happens when electrical energy is converted to heat and light?

In all the circuits you have built so far electrical energy has been converted into heat and light in a bulb.

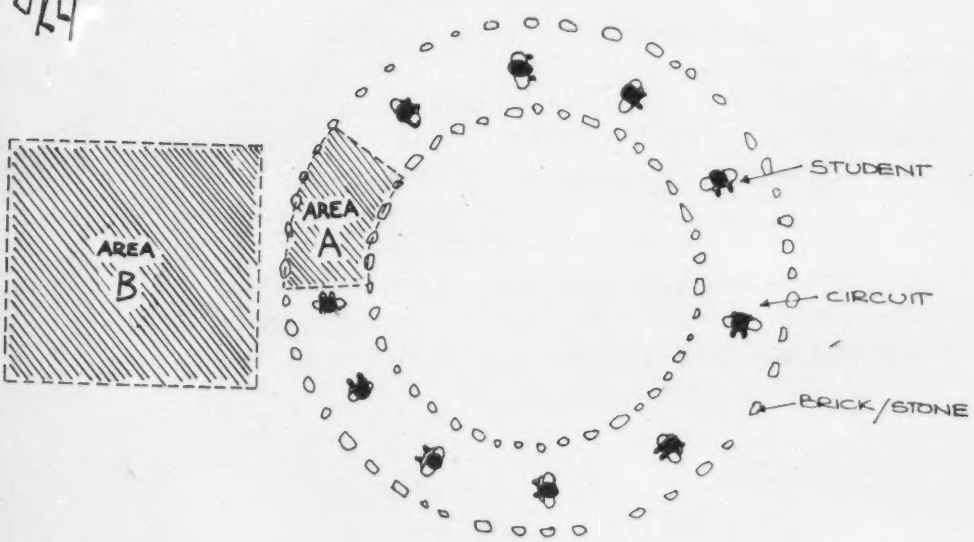
You will have noticed, I am sure, that the piece of wire which glows white hot inside the bulb is very thin.
Do you think this has anything to do with the energy conversion which goes on when a current is passing through the bulb?



You know that electrical energy is carried by the current.
Think about the problems in getting a current of water to pass through a narrow pipe and apply your thinking to electric currents.
Discuss your thoughts with your teacher.

To help you understand what is happening we are goint to use our 'pupil particle' model which we used in Unit C_2 when talking about matter.

Activity 5 : A Pupil Model Of A Circuit



The circuit without a group of stationary students represents a good conductor like copper. The moving students (current) moved (flowed) quickly and easily through the circuit (condutor). When a group of stationery students were placed in one part of the circuit (area A), the moving students (current) need more energy to move through the circuit because at A they had to force their way through. At A the stationary students RESISTED (tried to prevent) the movement of the current. To force their way through A, the moving students (current) had to use extra energy.

You can get the same effect by rubbing your hands together quickly for a few seconds.

Because your palms are rough, heat was produced by FRICTION because FRICTION RESISTS movement of the hands. For the hands to move, extra energy was used to overcome friction.

ELECTRICAL RESISTANCE

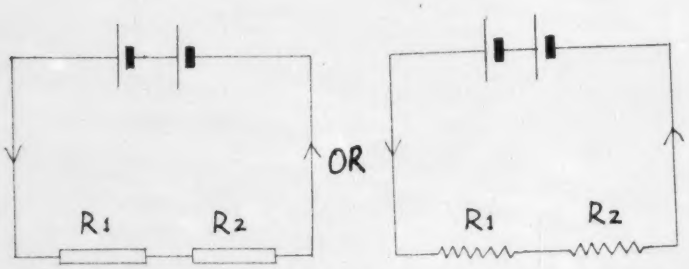
The thin wire in the bulb RESISTS the flow of electricity. A conductor like the thin wire which resists the flow of electric current is called a RESISTOR. The action of resisting the flow of electric current by a resistor is called RESISTANCE. Thus RESISTORS OFFER RESISTANCE TO THE FLOW OF ELECTRIC CURRENTS. To overcome this RESISTANCE energy is required. This ENERGY is converted to HEAT and if the resistor becomes white-hot LIGHT energy is also produced. Friction produces heat energy because it offers resistance to movement. Hence Resistance can be regarded as ELECTRICAL FRICTION caused by the electric current forcing its way past the particles in the thin wire.

Can you understand why a thin wire has more resistance than a thick one and a long wire has more resistance than a short one?
Discuss these questions with your teacher.
Does this explanation help you to understand resistors and resistance?

SYMBOL OF RESISTOR:

USE OF SYMBOLS IN CIRCUITS

A circuit that consists of two resistors in series can be drawn in symbols thus:



Do not forget that an electric bulb is a kind of resistor!

Conductors and Insulators again

Near the beginning of this unit (on Page 7) you learnt about conductors and insulators. Some conductors are better than others! You may remember that carbon allowed current through but not very much. Now you know why don't you?

All metals are good conductors of electricity (even mercury). Silver is the best followed by copper and then aluminium. Why do you think the wires which bring electrical energy from Kariba are made of Aluminium?
Discuss this with your teacher.

VOLTAGE, CURRENT AND RESISTANCE

Lets think about these three things, voltage, current and resistance.

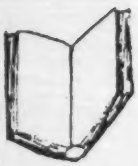
You have seen that the voltage of the source is a measure of available energy. Potential difference across a conductor is an indication of how much energy is being conducted between these two points.

Since the current needs energy in order to get through resistance in a conductor, the voltage of a source is <u>also</u> an indicator of how much current will flow through a resistance. If the voltage increases teh current increases for the same resistance.

If the voltage decreases the current decreases also for the same resistance. Scientists say the current is DIRECTLY PROPORTIONAL to the voltage if the resistance is constant. Of course, if we keep the voltage constant and change the resistance then the current will also change. If the resistance increases the current must decrease since only the same amount of energy is available.

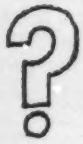
If you think about this it means that resistance gets bigger current becomes smaller; if resistance gets smaller current becomes bigger . Scientists say current is INVERSELY PROPORTIONAL to resistance as long as the voltage stays the same.

In the circuits you have experimented with all the energy conversions have been through resistance which converts the energy to heat and light. There is another conversion possible of course through a converter called an electric motor. This converts electric energy into kinetic energy.
You will learn about this converter in part II of this unit.



Now read and revise and do "How Much do you Know".

How much do you know? (2)



1. For an electric current to flow through a circuit there should be a ..... between the terminals of a cell or battery.
2. The unit of potential difference is ....., which is measured by a .....
3. To measure potential difference across a part of a circuit the ..... is always connected ..... to the circuit.
4. When cells are connected in series the combined voltage is the ..... of the voltage of each cell.
5. A dry cell is an inefficient source of electrical energy because .....
6. A car battery is an efficient source of electrical energy because .....
7. When does a short circuit happen?
8. What will happen to an electrical source if it is short-circuited?
9. What danger is likely to be caused by a short in the circuit?
10. What is a fuse?
11. Briefly explain how a fuse avoids the danger caused by a short in the circuit.
12. A Zim-Sci ammeter normally uses a 2A fuse. By mistake this fuse is replaced by a 5A fuse. The instrument is then connected to a circuit in which 3A flow.
    What will happen to (a) the fuse
    (b) the ammeter?

SUMMARY

1. Electricity is a form of energy.
2. In a complete circuit a torch bulb converts electrical energy to heat and light energy.
3. For an electric current to flow through a circuit a complete circuit is needed.
4. An open/incomplete circuit is one in which no current flows.
5. A switch is connected to a circuit to complete and break the circuit.
6. Substances/materials which allow electricity to flow through them are called conductors. Usually most metals are good conductors. Carbon and certain liquids also conduct electricity.
7. Substances which do not conduct electricity are called non-conductors (insulators). Most non-metals are non-conductors.
8. When the circuit is complete a current flows from the positive (+ve) to the negative (-ve) terminal.
9. A battery consists of at least two cells.
10. When cells are connected in series the voltage increases.
11. The current in a series circuit is the same throughout the circuit.
12. In a parallel circuit the main current from a battery splits into smaller currents which pass through each branch of the circuit and then joins up into a main current again before going back into the battery.
13. The unit of electric current is the ampere which is measured by an ammeter. The ammeter is connected in series in the circuit.
14. The unit of available electrical energy is a volt which is measured by a voltmeter. A voltmeter is connected parallel to an appliance in the circuit.
15. The p.d. across an appliance is a measure of the electrical energy needed to drive the current through it or the energy being converted into other forms of energy.

16 Efficient electrical energy sources use very little energy to drive currents through themselves.

17 A short circuit takes place when the terminals of an electrical energy source are connected directly by a good conductor.

18 A fuse is a wire/conductor which melts easily when too large a current (caused by a short in the circuit) passes through it.

20. Resistance is the property of a conductor which causes energy to be needed for an electrical current to pass through. It is like friction and the energy is converted to heat.